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4 **APPARATUS AND METHOD FOR SEPARATING IMPURITIES FROM A STREAM**

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9 **BACKGROUND OF THE INVENTION**

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11 This invention relates to an apparatus for separating impurities from a stream. More  
12 particularly, but not by way of limitation, this invention relates to an apparatus and method for  
13 separating impurities from a stream utilizing centrifugal forces.

14 Reverse osmosis (RO) is a filtration process for the removal of ionic and organic pollutants  
15 from wastewater. Prior art techniques utilize a filtration process by which large arrays of high  
16 pressure piping and pressure pumps direct the affluent to filters. This process yields low volumes  
17 of filtrated output (permeate), utilizes large areas for pipe array ad components and concentration  
18 polarization and membrane fouling hinders the wide application of RO filtration process.

19 Prior art RO, ultra filtration, and nano filtration utilizes a static pressure flow across  
20 membranes to induce filtration. This process uses pressure vessel piping which causes a build up  
21 of sedimentation against these membranes which hinders the function of the cross flow  
22 membranes which results in a decrease in filtrate flux. This concentration polarization and

membrane fouling limits the volume of permeate production which leads to not utilizing the standard RO process as a viable alternative to disposal.

Therefore, there is a need for an apparatus and method that will remove ionic and organic pollutants from a stream. There is also a need for an apparatus and method that will provide for an efficient reverse osmosis process. These and many other needs will be met by the invention herein disclosed.

## SUMMARY OF THE INVENTION

A filtration apparatus for filtering a stream is disclosed. The apparatus comprises a rotor member having an inner portion and an outer portion. The rotor member comprises an inlet for the stream; an array of cavities operatively arranged to receive the stream from the impeller, with the array of cavities being arranged at a angle of between 45 degrees and 10 degrees relative to a horizontal axis of the rotor member. The rotor member further includes means, operatively positioned within the array of cavities, for separating the impurities from the stream, and a permeate outlet for delivering a permeate from the rotor bowl. The apparatus may also contain drive means, operatively connected to the rotor member, for rotating the rotor member so that the stream is exposed to a centrifugal force.

In one preferred embodiment, the rotor member contains a baffle plate to distribute the stream about the inner portion. The rotor member may also contain an impeller vane arranged on the inner portion of the rotor bowl and wherein the impeller vane is adapted to receive the stream.

1           The separating means may comprise a spiral wound membrane cartridge adapted to fit  
2        within the cavities. In one preferred embodiment, the rotor bowl contains a retentate outlet for  
3        delivering the retentate from the rotor bowl. The retentate outlet of the rotor member may  
4        contain a back pressure valve for regulating the pressure within the retentate outlet and keeping  
5        the retentate flowing in a radially inward direction. In the most preferred embodiment, the  
6        permeate outlet is directed to the outer portion of the rotor bowl so that the permeate is directed  
7        radially outward. Also in the most preferred embodiment, the retentate outlet is directed to an  
8        inner chamber located radially inward from the array of cavities so that the retentate is directed  
9        radially inward. In the preferred embodiment, the filter array is orientated at a angle between 60  
10      degrees and 10 degrees relative to the horizontal axis of the rotor member, and in the most  
11      preferred embodiment, the filter array is orientated at an angle of approximately 45 degrees  
12      relative to the horizontal axis of the rotor member.

13           A method of separating an affluent is also disclosed. The method comprises providing a  
14        rotor apparatus, and wherein the rotor apparatus comprises a rotor member including an inlet for  
15        the stream; an array of cavities operatively arranged on the outer periphery of the rotor apparatus  
16        and adapted to receive the affluent; a membrane, positioned within the array of cavities, for  
17        separating the impurities from the stream; and, a permeate outlet for delivering a permeate from  
18        the rotor bowl. The method further includes flowing the affluent to the inlet of the rotor  
19        apparatus and rotating the rotor apparatus. A centrifugal force is created within the inner portion  
20        of the rotor apparatus so that the affluent is forced to the outer periphery of the rotor apparatus.

21           The method further includes directing the affluent to the array of membranes arranged on  
22        the outer periphery of the rotor apparatus and separating the affluent in the membrane into a

1 permeate stream and a retenate stream. Next, the permeate is produced from the rotor apparatus  
2 and the retentate stream is also produced from the rotor apparatus. In one preferred embodiment,  
3 the step of directing the affluent to the array of membranes includes channeling the affluent about  
4 a baffle arranged within the inner portion of the rotor apparatus. Also, the step of directing the  
5 affluent to the array of membranes includes channeling the affluent to a plurality of impeller vanes  
6 arranged on the inner portion of the rotor apparatus.

7 In one preferred embodiment, the permeate outlet is directed to the outer portion of the  
8 rotor bowl and wherein the step of producing the permeate includes directing the permeate  
9 radially outward. The method may also include the step of producing the retentate stream from  
10 the rotor apparatus by directing the retentate to an inner chamber located radially inward from the  
11 array of cavities so that the retentate is directed radially inward. Additionally, the method may  
12 include controlling the back pressure within the retentate outlet when producing the retentate  
13 stream from the rotor apparatus.

14 An advantage of the present invention is the centrifugal force that is created mimics  
15 pressures set up in a static pressure vessel by the tangential escape vector through the apparatus.  
16 Another advantage is that the present invention can use prior art vertical centrifuges that can be  
17 retrofitted to contain the membranes. Still yet another feature is that the present invention can be  
18 used as a reverse osmosis process to remove ionic and organic pollutants from a stream.

19 A feature of the present invention is that the created centrifugal forces also set up vortices  
20 which induce a spiral flow through the membrane that promotes sediment discharge enhancing the  
21 flux improving permeate volumes and membrane performance. Another feature is that the desired  
22 rotation speed of the centrifuge is determined by the desired filter pressure and type of filtration to

1 be utilized. Another feature is a rotor bowl that holds the filter array that utilizes the force of the  
2 tangential escape vector velocity for particle separation. Another feature is that the filter array  
3 can be arranged about the periphery of the rotor bowl at an angle varying between 20 degrees to  
4 50 degrees relative to the horizontal axis of the rotor bowl.

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7 **BRIEF DESCRIPTION OF THE PREFERRED EMBODIMENTS**

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9 **FIGURE 1** is a partial cross-sectional view of the rotor member of the present invention.

10 **FIGURE 2** is an isometric view of an exploded view of the rotor member seen in **FIGURE 1**, which includes the rotor bowl and rotor cone.

11 **FIGURE 3** is an isometric view of the rotor cone seen in **FIGURE 2**.

12 **FIGURE 4** is a partial cross-sectional view of the assembled apparatus of the present  
13 invention.

14 **FIGURE 5** is a partial cross-sectional view of the rotor member seen in **FIGURE 1**.

15 **FIGURE 6** is an exploded partial cross-sectional view of the membrane within a cavity.

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18 **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

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20 **Referring now to Fig. 1**, a partial cross-sectional view of the rotor member **2** of the  
21 present invention will now be described. More specifically, the rotor member 2 comprises a rotor

1 cone 4 that is operatively connected to a rotor bowl 6. The rotor cone 4 has an outer conically  
2 shaped wall 8. At the apex of the outer wall 8 is the inlet 10, and wherein the inlet 10 will allow  
3 for the entry of the stream as will be explained in greater detail later in the application. Extending  
4 radially inward, the rotor cone 4 has an inner conically shaped wall 12 that extends to the baffle  
5 14, and wherein the baffle 14 extends about the periphery of the inner wall 12. The stream will be  
6 directed through the inlet 10 and the centrifugal force will tend to force the stream to the inner  
7 wall 12. The baffle 14 will then channel the stream radially inward, as will be described in greater  
8 detail later in the application.

9 The rotor cone 4 also contains a circumferential cavity, denoted by the numeral 16, and  
10 wherein the circumferential cavity 16 has contained therein internal thread means seen generally at  
11 18. The rotor cone 4 will be threadedly connected to the rotor bowl 6. More specifically, the  
12 rotor bowl 6 contains a circumferential ridge 20 and wherein the circumferential ridge 20 has  
13 external thread means 22 that are configured to engage the internal thread means 18 so that the  
14 rotor bowl 6 is attached to the rotor cone 4. It should be noted that other means for attachment  
15 are possible such as pinning the cone 4 and bowl 6 together.

16 The rotor bowl 6 contains an outer conically shaped wall 24. As seen in Fig. 1, when the  
17 rotor cone 4 and the rotor bowl 6 are attached, the rotor member 2 has a conical shape. Fig. 1  
18 shows that the outer wall 24 contains outlets 26, 28 for the permeate, as will be described later in  
19 the application. The rotor bowl 6 contains an underside 30 of the rotor bowl 6 that in turn  
20 extends to an inner circular cavity, denoted by the numeral 32, and wherein the inner circular  
21 cavity 32 extends to the base pedestal 34. The retentate channels 35a, 35b are shown and  
22 wherein the retentate channels 35a, 35b direct the retentate into the cavity 32. The retentate is

1 the stream that has not been filtered and still contains undesirable components. The base pedestal  
2 34 will be connected to the drive mechanism for rotating the rotor member, as will be described  
3 later in the application. Fig. 1 also shows the retentate channels 35c, 35d.

4 The rotor bowl 6 has a topside 36 and wherein the topside 36 contains the circumferential  
5 ridge 20. The topside 36 contains a plurality of angled bores seen generally at 38, 40. In the  
6 preferred embodiment, the angle of the bore is between 70 degrees and 10 degrees relative to  
7 horizontal, and in one preferred embodiment, the angle is between 50 degrees and 20 degrees  
8 relative to horizontal, and in the most preferred embodiment is 45 degrees relative to horizontal.  
9 The bores 38, 40 will have contained therein membrane members and wherein the membrane  
10 members will be in one preferred embodiment spiral wound membranes. Fig. 1 shows membranes  
11 45a, 45b disposed within bores 38, 40. The membranes will be discussed in greater detail with  
12 reference to Fig. 6. Returning to Fig. 1, the topside 36 also contains a plurality of impeller vanes  
13 such as seen at 42, 44. The impeller vanes 42, 44 receive the stream from the baffle 14 and  
14 directs the stream to the bores 38, 40 for separation within the membranes.

15 The flow in Fig. 1 is represented by flow arrows as the rotor member 2 is being rotated.  
16 The flow arrows "A" depicts the stream entering the inlet 10. The arrows "B" represent the  
17 stream that has been forced into the inner wall 12 due to the centrifugal force. The pressurized  
18 stream will be directed radially inward "C" due to the baffle 14, and in turn, the stream is  
19 channeled into the impeller vanes 42, 44. The pressurized stream, energized by the centrifugal  
20 force created due to the rotation of the rotor member 2, will be separated within the membranes  
21 45a, 45b as seen by arrows "D". The separated stream (referred to as the permeate) is collected  
22 from the center tubes 46a, 46b of the membranes 45a, 45b and the permeate outlets 26, 28 are

1 aligned with the center tubes 46a, 46b in order to channel the permeate radially outward from the  
2 rotor member 2 as seen by arrows "E". The retentate is produced via the channels 35a, 35b from  
3 the membrane that has not entered the center tube (i.e. unfiltered fluid), as denoted by the arrow  
4 "F" into the circular cavity 32. Note that both the retentate and the permeate will continue to be  
5 pressurized which in turn aids in removing the retentate and permeate from the rotor member 2.

6 A discussion of the flow through the membranes will be described with reference to Fig. 6.

7 Referring now to Fig. 2, an exploded isometric view of the rotor member 2 seen in Fig. 1  
8 will now be described. The rotor member 2 includes the rotor bowl 4 and rotor cone 6. The  
9 impeller vane assembly 50 is shown in Fig. 2. The impeller vane assembly 50 consist of a plurality  
10 of impeller vanes. For instance, the impeller vane 42 and the impeller vane 44 from Fig. 1 are  
11 shown. The impeller vanes are rigid, with a vertically extending surface radially mounted on the  
12 top side of the rotor bowl 6 that directs the stream to the angled bores and more particularly to  
13 the membranes. Fig. 2 depicts a total of eight (8) vertically extending vanes, namely vanes 42, 44,  
14 51a, 51c, 51d, 51f, 51g.

15 In the preferred embodiment shown in Fig. 2, there are eight (8) angled bores included  
16 within the rotor member, namely the bores 38, 40 (previously described) as well as the bores 52,  
17 54, 56 (not shown in this view), 58, 60, 62 (not shown in this view). In the most preferred  
18 embodiment, each bore will have an impeller vane that aids in directing the stream from the baffle  
19 to the membranes. Thus, the baffle 14 directs the stream that has been energized with the  
20 centrifugal force to one of the impeller vanes, namely vanes 42, 44, 51a, 51b, 51c, 51d, 51f, 51g  
21 which in turn directs the energized stream to the bores 38, 40, 52, 54, 58, 60, 62. As mentioned  
22 earlier, the bores 38, 40, 52, 54, 58, 60, 62 will contain membranes that are used for separation

1 and filtration purposes. Fig. 2 also depicts the permeate outlets 26, 28, as well as permeate  
2 outlets 29a, 29b, 29c, 29d.

3 In Fig. 3, an isometric view of the rotor cone 4 seen in Fig. 2 will now be described. This  
4 view depicts the underside portion of the rotor cone 4 so that the internal threads 18 are shown,  
5 along with the baffle 14. In the most preferred embodiment, the baffle 14 extends about the  
6 periphery of the internal rotor cone 4 so that the stream that has been forced radially outward will  
7 come into contact with the baffle 14 and wherein the baffle 14 will then direct the stream to the  
8 impeller vane assembly 50 (not shown in this view).

9 Referring now to Fig. 4, a partial cross-sectional view of the assembled apparatus of the  
10 present invention will now be described. The rotor bowl 6 is fixedly attached to a drive means 64,  
11 such as an electric motor, for rotating the rotor bowl 6. The rotor member 2 is generally encased  
12 within an outer shell 66. The outer shell 66 includes an inlet passage 67 for the incoming stream.  
13 The outer shell 66 also includes a permeate outlet 68 that is operatively associated with all the  
14 permeate outlets (in this view showing outlets 26, 28), and wherein the first outlet 68 will direct  
15 the energized permeate from the outer shell 66 as shown by the arrow "G". The outer shell 66  
16 further includes a retentate outlet 70 that is operatively associated with the retentate outlet  
17 channels (in this view showing outlet channels 35a, 35b), and wherein the second outlet 70 will  
18 direct the energized retentate from the rotor member 2 as shown by arrow "H".

19 In Fig. 5, which is a partial cross-sectional view of the rotor member 2, the cavity 32 is  
20 shown, and wherein the cavity 32 is shown as an inner circular cavity, wherein the retentate  
21 channels, for instance retentate channel 35a and retentate channel 35c, is directed radially inward  
22 to the cavity 32. The impeller vane assembly 50 is also shown as well as the permeate outlets

1 29a, 26, 29b, 29a.

2 Fig. 6 is an exploded partial cross-sectional view of the membrane 45a taken from Fig. 1.

3 Hence, as the stream is channeled via the impeller vanes 51a, 44, 51b, 51c, 51d, 42, 51f, 51g, the  
4 stream (which is under pressure due to the centrifugal force, and is referred to as the energized  
5 stream) will enter into the membrane 45a. The membrane 45a may be a spiral wound membrane  
6 member that is commercially available from The Dow Chemical Company under the name  
7 FILMTEC Membranes. Membranes for reverse osmosis come in a variety of membrane materials  
8 but two important kinds are the thin-film composite membranes and the cellulose acetate  
9 membranes. It should be noted, however, that with respect to the invention herein disclosed, the  
10 specific composition of the membrane does not matter. In the preferred embodiment, the  
11 membrane will be configured in the spiral wound cartridge design with a perforated permeate tube  
12 46a, outer housing and flow pattern as shown in Fig. 6.

13 Fig. 6 also depicts the back pressure valve 80 that is placed into the retentate channel 35a  
14 in order to regulate pressure within the membrane 45a and the outlet 26 which in turn prevents  
15 back flow back through the membrane 45a to the impeller vanes. The back pressure valve 80 is  
16 commercially available from Circle Seal Controls Inc. under the name 5100 Series Valve. As  
17 understood by those of ordinary skill in the art, the stream will interact with the membrane and  
18 wherein the filtered fluid (referred to as the permeate) will be directed to the center tube 46a (see  
19 arrows "J"). From the center tube 46a, the permeate will be directed to the permeate outlet 26  
20 (see arrow "E"). The unfiltered fluid (referred to as the retentate) will be directed through the  
21 membrane 45a (see arrows "D") and then to the retentate channel 35a (see arrow "F") which in  
22 turn is directed to the cavity 32. Note that the center tube 46a is perforated and aligned with the

1 permeate outlet 26, while the remainder of the cross-sectional area of the membrane 45a will be in  
2 communication with the retentate channel 35a. Hence, the stream "D" at the end of membrane  
3 45a will enter the retentate channel 35a.

4 Although the present invention has been described in terms of specific embodiments, it is  
5 anticipated that alterations and modifications thereof will no doubt become apparent to those  
6 skilled in the art. It is therefore intended that the following claims be interpreted as covering all  
7 such alterations and modifications as fall within the true spirit and scope of the invention.

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